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# Optimal Road User Charges and Income Distribution in Kenya

by
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## ABBREVIATIONS

| | |
|---|---|
| $w_{rv}$ | Weight attached to private sector relative to public sector |
| d | Value of marginal increase in consumption at any observed level relative to marginal increase in average consumption |
| MPK | Value of marginal average consumption relative to marginal increase in public income |
| KShs | Kenya Shillings. Twenty Kenya Shillings is equivalent to one Canadian dollar as at December 1990. |
| MC | Marginal cost |
| SRMC | Short Run Marginal Cost |
| AVC | Short Run Average Variable Cost |
| GDP | Gross Domestic Product at 1982 market prices |
| HH | Household |
| HGoods | Heavy Goods Vehicles. It includes all vehicles used for purposes of transporting merchandise |
| $Q_{rv}$ | Vehicle-kilometre |

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## ABSTRACT

In this paper a method of calculating optimal road user charges taking into account distributional considerations is presented. The proposed method uses a second best pricing policy in calculating the optimal level of road user charges. This method is an improvement over previous work which uses average cost in calculating optimum level of road user charges. It leads to optimal road use charges in which users pay for the social cost of their road use and, at the same time, ensures an equitable income distribution.

The main conclusions are [i] price and income are important determinants of vehicle-kilometres travelled [ii] second best solution (efficiency and equity) can be achieved by use of a single pricing policy and, [iii] vehicle users have not been paying the true social cost of road use as reflected by the differences in efficient and existing charges.

**KEY WORDS:** transport economics, demand for transport, income distribution, optimal road user charge.

## RESUME

Dans ce mémoire nous proposons une méthode pour calculer la tarification routière optimale en tenant compte des effets de distributions. L'utilisation des coûts routiers marginaux assurent que la tarification proposée réflète adéquatement les coûts sociaux de l'infrastructure routière. Ce travail prolonge les travaux antécédents de différentes façons: une estimation économétrique des demandes de transport par catégorie est effectuée et l'évaluation des coûts routiers proviennent des coûts marginaux plutôt que des coûts moyens. Ces améliorations méthodologiques conduisent à une tarification optimale du transport routier, puisque les usagers font face aux coûts réels, et tient compte des effets de répartitions sur les revenus.

Les conclusions sont: 1) le prix et les revenus sont des facteurs déterminants du nombre de déplacements véhicules-kilomètres; 2) les tarifs routiers existants sont inférieurs à ceux dérivés d'une tarification optimale; 3) la tarification actuelle favorise davantage les passagers des autobus et le transport des marchandises que les usagers de l'automobile.

**MOTS-CLES**:économie des transports, demande de transport , distribution des revenus, tarification routière optimale.

# OPTIMAL ROAD USER CHARGES AND INCOME DISTRIBUTION IN KENYA

## 1.0 INTRODUCTION

Kenya's road system is one of the most impressive public investments in East Africa. Encompassing nearly 50.9 million kilometres, the system of Trunk, Primary, Secondary, Minor and Other roads handles about 12.2 million vehicle-kilometres of travel each year [Ministry of Public Works (MOPW), Traffic census, 1988 pp. 12]. Its value approaches KShs. 7.542 billion, nearly 43 per cent of the total output of the Transport and Communications Sector [Economic Survey 1988, pp. 138].

Large public spending is required each year for construction and maintenance of the road system. As shown in Table 1, the share of annual disbursement for road development increased from 69 per cent in 1975 to 84 per cent in 1985. The table also reveals some disturbing trends. Disbursement for maintenance expenditures continued to decline over the same period, indicative of the difficulty of providing for maintenance of the road system. Indeed, there exists a widening gap between actual and approved recurrent expenditure which includes wages, operation and maintenance costs of the roads. The responsibility of closing the gap falls differentially to MOPW and Local Authorities, whose resources are also seriously strained. Total motor vehicle revenue however has continued to rise. This is attributed to the over all policy of the central government to raise revenue through taxing both vehicle and road users. It is further observed that, the road transport sector's need for public funds continues to grow. As the last row in the table shows, total disbursements more than doubled between 1975 and 1985.

The growing problem of road maintenance compelled the government to introduce toll charges in 1986. Revenue generated from toll collection is exclusively used for road maintenance. While it is generally agreed that revenue from toll and other user fees contribute additional resources for road

Table 1: Road Revenues and Disbursements for 1975 to 1988

in KShs. million

| | 1975 | 1980 | 1985 | 1988 |
|---|---|---|---|---|
| REVENUES | | | | |
| 1. Licences | 59.7 | 120.84 | 205.84 | 304.98 |
| 2. Fuel Cons Tax | n/a | 599.52 | 1198.2 | 2673.66 |
| 3. Duty on Fuel | 245.3 | 25.06 | 292.58 | 490.3 |
| 4. Other Imports | 167.2 | 445.52 | 434.94 | 904.18 |
| 5. Toll Fees | n/a | n/a | 68.48 | 130.62 |
| TOTALS | 472.2 | 1190.94 | 2200.04 | 4506.74 |
| DISBURSEMENTS | | | | |
| 6. Capital outlays | 364.7 | 7711.3 | 9987.4 | 8598.2 |
| | (69) | (72) | (84) | (83) |
| 7. Maintenance | 163.39 | 300.35 | 183.66 | 169.08 |
| | (31) | (28) | (16) | (17) |
| TOTALS | 528.09 | 8011.65 | 10171.06 | 8767.28 |
| | (100) | (100) | (100) | (100) |

Note: Source data on disbursements are recorded in financial years. We therefore calculated the average of two corresponding financial years to present the information in the format provided.

( ) are percentage shares of the total disbursements.

Sources: Statistical Abstracts [1984, pp.180; 1989, pp.178; 1974, Table 204; 1980, Table 226; 1984 and 1987, Tables 199; 1989, Table 199(b)] and Data collected by Road Tolls Department (MOPW).

maintenance, no economic analysis has been undertaken to assess whether the charges are optimal for different road users on different road types.

One important policy issue is that of income distribution[1]. The Kenyan government has pursued a range of policy objectives, the most basic of which is to improve the standard of living of the population through income redistribution. Fiscal policies are the primary instruments used to redistribute income. The belief in fiscal policies presumes that they can be effective in bringing about an equitable redistribution of economic benefits. On the contrary experience shows that this may be an unreasonable belief. But even if fiscal policies could be effective the political reality may prevent their implementation. In addition the welfare loss may also outweigh the expected welfare gains. Several reasons[2] can be advanced to explain this fact.

In spite of the government efforts, there is no doubt that there exist strong income inequality in Kenya. There is ample empirical evidence to support this claim. The first body of evidence can be found in the ILO Report [1972, pp.96]. Other studies, for instance, "Kenya: Into the Second Decade", "Redistribution With Growth" [Chenery et al, 1974], "Size and Distribution of Income: A Compilation of Data" [Jain S., 1975] based their findings on the ILO Report as their primary source. These studies show that about 20 per cent of the Kenyan population receive 70 per cent of the total income. The distribution reported refers, as does the ILO Report, to both monetary and non-

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[1] There is no hard and fast definition of income distribution. Generally cited types of income distribution are "functional distribution" and "size distribution". Functional distribution refers to the division among the factors of production such as land, labour and capital. Size distribution refers to the distribution of income of all kinds among individuals or families, which are divided into categories based on the levels of family income. The latter is most commonly used as a direct measure of welfare. Since we are concerned with income distribution between persons or group of persons, distribution of income herein refers to "size distribution".

[2] These include technological and resource constraints, distortion of market prices, administrative costs and the political pressure of the rich - all of which may individually or jointly prevent government efforts from redistributing income through fiscal measures. See also, Kirkpatrick [1979, pp. 139-141]

monetary incomes. In a study of inequality, poverty and development, Ahluwalia [1976, pp. 340] estimated income distribution for sixty developing countries. His study reveals that in Kenya the poorest 20 per cent earns 3.8 per cent of per capita income. The second, third and fourth quintiles receive 6.2, 8.5 and 13.2 per cent respectively. The top 20 per cent receives 68 per cent of the per capita income. Mackay and Taylor [1989, pp. 112-114] argue that macro-economic and social indicators grossly mask severe inequalities and, that Kenya has a highly skewed distribution of income. They report a Gini coefficient estimate which has varied between 0.6 in the early 1970s and 0.5 to 0.55 in the mid 1970s [House and Killick, 1983]. Despite questions regarding the reliability and adequacy of the data used in these studies it seems reasonable to conclude that a significant degree of income inequality persists in Kenya. Recognizing the limitations of fiscal policies in bringing about income redistribution and the restricted number of policy options available, a single policy variable can be used to achieve different objectives. Road user charges is one of such variables.

In designing appropriate pricing policy for road users, average cost pricing has been used extensively by different analysts. While there are arguments in favour of this approach, its application will not generally result in an efficient allocation of resources. This is because it understates the true social cost of road use. Adler [1967], for example, has shown that road users pay for less than half of the total road costs in Latin America and recommends that the social cost of road use should paid by users.

Marginal cost (MC) instead is a more realistic measure of true cost than average cost though admittedly difficult to estimate. An efficient user charge requires knowledge of MC. In addition to efficiency in pricing, marginal cost pricing approach produces net benefits which could potentially help both the rich and the poor depending on their distribution.

This study attempts to derive a method of calculating the optimum level of road user charges taking into account the distribution consequences of the policy. We begin with the theoretical model and a review of the literature. This is followed by an empirical estimation of; i) demand function and, ii) parameters of the theoretical model presented earlier. Finally, the parameter estimates are used to estimate the optimum level of road user charges. The obtained road user charges are then compared with the existing level of road user charges.

## 2.0 LITERATURE REVIEW AND MODEL SPECIFICATION

In Kenya research in transport has not attracted adequate attention although 25 per cent of the annual national budget goes to the transport sector. Much attention has however been given to urban transport problems especially in Nairobi. Not surprisingly, the trend is similar to that of the developed countries whose transport research efforts is predominantly in the Urban centres.

A number of studies have been undertaken and these include Urban Study Group [1973], Packpoy and Associates [1977], Kapila et al [1982], Transurb Consultants [1986], Osundwa [1987] and Mwania [1989]. All these studies concentrated on the question of modal choice and provision of urban transport. For example, Osundwa examined the choice of commuting modes in an urban sector: a case study of Nairobi City. The study reveals that in the study area (Kibera) personal attributes (age, sex and education) do not affect commuters decision to chose one mode over another. The study also finds that the income elasticities of demand for transport services are positive and consistently less than unity. Mwania looks at the modal choice in cargo haulage for the Mombasa - Nairobi route. He examined the determinants of modal choice and the general process of cargo handling in two modes - railway and road. He shows that the relative freight charges and delivery time are the most important variables in determining the modal choice in cargo haulage. In addition, changes in freight charges could result in a shift of demand from one mode to another.

The most comprehensive study is the Kenya-Danida [1980]. This was an engineering, architects and economists consultancy report on the study of road user charges and axle load limits in Kenya. This study quantified the damage caused by different classes of vehicles to different highways and the proportion of revenue each class contributes to cover costs, in order to determine the existence of any subsidy. It examined and estimated a system of road user taxation which allocates the fiscal burden between road transport and other modes of transportation to promote

competition. And finally, the study determined economically optimal axle load limits and estimated the most suitable configuration of axles and vehicle combinations [Kenya-Danida, 1980, pp. 1-1]. The estimated total road user charges (see Table 2) were based on the short run marginal cost of road transport. Though relevant the study did not explicitly address optimal pricing policy and income distribution.

Table 2: Total Road User Charges - Shs. per vehicle-kilometre

| | Paved | Unpaved |
|---|---|---|
| Passenger Cars | 0.494 | 0.487 |
| Light Goods Vehicles | 0.529 | 0.495 |
| Light Goods Vehicles[1] | 0.[illegible]0 | 0.385 |
| Buses | 0.395 | 0.617 |
| Heavy Goods Vehicles | | |
| 2 Axle | 0.407 | 0.422 |
| 3 Axle | 0.503 | 0.526 |
| 4 Axle | 0.685 | 0.716 |
| 5 Axle | 0.767 | 0.802 |
| 6 Axle | 0.838 | 0.877 |

Note: 1: Light Goods Vehicles used as passenger vehicles.

Source: Kenya-Danida Study [1980, Table 6.03]

The question of optimal road user charges and income distribution in Kenya has not been addressed extensively. Some economists such as Wohl and Hendrickson [1984], Mohring and Harwitz [1962] showed that optimal pricing and investment decision for highways can be dealt with analytically in a single model. A Peak-load pricing scheme was analyzed by Vickrey in Fitch [1964], Strotz [1964], and Mohring [1970]. Later, Keeler and Small [1977] derived a long-run model of highway pricing and investment.

Thomas [1978] studied road investment and pricing in developing countries: the case of Ghana. The study made attempts to reassess the desirability of major road investment in the light of new distributional priorities and explored whether the subsequent implications could be modified by a policy of road pricing. The study concludes that improvement of roads will do little to uplift the position of the poor in the developing countries. Instead, inclusion of distributional objectives should lead to a reassessment of the role and desirability of road pricing. This study demonstrates that distributional considerations can be integrated into the process of appraising road projects. The study concludes that, this allows aid donors to provide indirectly the recurrent financial support that they are so reluctant to provide directly. It does not however tackle the issue of optimal pricing policy and income distribution.

Kirkpatrick [1979] studied the distributional objectives and optimum level of road user charges in Kenya. He estimated the optimal road user charges based on the average variable truck costs. The estimated road user charges were compared with the existing level of road user charges. Results of the analysis confirms that where distributional considerations are included in the determination of the pricing policy, the optimum structure of charges diverges significantly from a system of charges based on the efficiency criterion alone.

The Kirkpatrick study demonstrates that income distribution aspects can be incorporated in

transport pricing, however, it does not produce results that are optimal for policy purposes. This is so, because different types of vehicles impose varying costs on different road types and vice versa. Inevitably, disaggregation of road types and vehicle classes is necessary in such an analysis. Such disaggregation was not fully examined in the Kirkpatrick study.

The present study extends the work of Kirkpatrick by disaggregating the demand function by road and vehicle types and also applies a "second best pricing policy", that is, a pricing policy that hopes to achieve some degree of efficiency and equity. We assume that the road network is given and that there is no congestion on the roads. Walters [1968], for example, showed that in practice many rural and inter-urban roads are approximately pure public goods, thus congestion is so infrequent and small that it can be ignored. We also, distinguish between paved and unpaved roads. Paved roads make up 26 per cent of the total road length and carry about 85 per cent of total travels. Unpaved roads comprise 48 per cent of the network and carry only 5 per cent of the travels [Traffic Census, 1988]. Vehicles are classified into cars, buses and heavy goods vehicles.

Demand definition and classifications adopted are important for three main reasons. First, from the supply side additional damage on roads increase exponentially with different axle load limits on paved as well as on unpaved roads. For example buses cause close to three times more damage than cars on paved roads. On unpaved roads there is no major difference between damage caused by buses vis avis cars. A six axle load vehicle causes as much as six times more damage than cars on paved roads, and two and a half times as much on unpaved roads [Kenya-Danida 1980, Table 6-12]. This means that the marginal cost of road use varies with vehicle classifications. Similarly vehicle operation costs vary with the condition and type of road. Second, from the demand side it is reasonable to argue that the demand for transport services can be grouped by users income and vehicle type. Those who are relatively rich often travel by cars. The middle income and low income businessmen tend to travel by buses [Howe, 1971]. And assuming competition in the transport and

distribution industry, both consumers and producers benefit equally from the merchandise transported by the heavy goods vehicle. Third, the classification adopted in this study are similar to those used by the MOPW and Kenya-Danida study.

The demand for road use is then defined as

$$P_{rv} = P_{rv}(Q_{rv}) \qquad (2.1)$$

where $P_{rv}$ is the total user charge of a trip on a route excluding the cost of travel time and $Q_{rv}$ is vehicle-kilometre. The subscripts r and v stand for road type and vehicle class respectively.

Total benefits is normally given by the area under the demand curve. We represent this by the following expression

$$F_{rv}(Q_{rv}) = \int_0^{Q^*_{rv}} P_{rv}(Q_{rv})\, dQ_{rv} \qquad (2.2)$$

Total benefits can be divided into two parts. First is total expenditure or income to the government ($P_{rv}.Q^*_{rv}$) and second is the consumer surplus triangle ($m_{rv}(Q_{rv})$). This is denoted by

$$F_{rv}(Q_{rv}) = P_{rv}.Q_{rv} + m_{rv}(Q_{rv}) \qquad (2.3)$$

If the sole objective of the government is to maximize the net benefits in the road sector, then the objective function can be written as

$$Max \quad F_{rv}(Q_{rv}) - C_{rv}(Q_{rv}) \qquad (2.4)$$

where $C_{rv}(Q_{rv})$ is the cost of road use. Differentiating with respect to $Q_{rv}$, we get the first order necessary condition

$$F'_{rv}(Q_{rv}) - C'_{rv}(Q_{rv}) = 0 \qquad (2.5)$$

Hence obtain the classical condition of optimality, that is, $C'_{rv}(Q_{rv}) = P_{rv}(Q_{rv})$. If efficiency is the sole criteria of optimal pricing, then the rule is to set road user charges equal to the marginal cost of road use.

The Short Run Marginal Costs (SRMC) could be different from Average Variable Costs (AVC). The difference[3] emerges from the fact that the AVC increases infinitesimally with changes in the units of $Q_{rv}$. Congestion is normally considered a major factor that explains the difference between MC and AVC. However, the Kenya-Danida study [1980] shows, that other variables such as additional costs of road damage, costs to society due to increased accident risks, environmental costs etc., could also explain the difference. The SRMC thus reflects the true social cost of road use. It is reasonable to argue that "average variable cost pricing policy will cause facilities to be over-utilized and total net benefits to be less than their maximum". Marginal cost pricing therefore plays the central role in assuring that facilities are utilized most efficiently in economic terms. Of secondary importance is that whenever possible, the cost incurred in providing the transport services are paid for by those using and enjoying the benefits of such services. Although marginal cost pricing is not explicitly used in this analysis, the second best policy adopted can be argued to be superior than average cost pricing.

To allow for distributional objectives in the model it is necessary to identify the inter-sectoral division of net benefits and increase in income that, accrues to different groups within the economy. Two broad sources of benefits are identified; [i] benefit to public sector and [ii] benefit to private sector. Benefit to the private sector can further be classified into six categories of consumers. Those

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[3] Let $AVC = TVC(Q_{rv})/Q_{rv}$. Differentiating with respect to $Q_{rv}$ and rearranging terms we obtain $SRMC = AVC + (\partial AVC/\partial Q_{rv})*Q_{rv}$ so that $SRMC - AVC = (\partial AVC/\partial Q_{rv})*Q_{rv}$. If the RHS term is positive then the SRMC > AVC and both are positively sloped (see the AVC and SRMC graphs on page 12).

who use cars, buses and heavy goods vehicles, and each of the three is further re-grouped by paved and unpaved roads. The private benefit to each of these groups is given by $m_{rv}(Q_{rv})$.

The net benefit to the public sector can be written as

$$\sum_{r}\sum_{v}[F_{rv}(Q_{rv}) - C_{rv}(Q_{rv})] - [m_{rv}(Q_{rv})]$$

This is interpreted as the area bound by the demand curve and the amount of travel minus the cost and the consumer surplus attainable at that level of road use.

The private sector benefit is measured by the consumer surplus triangle. With the disaggregation already defined the aggregate consumer surplus is simply the sum of different surpluses. Figure 1, depicts the two types of benefits discussed above. The area $ABP^{*}_{rv}$

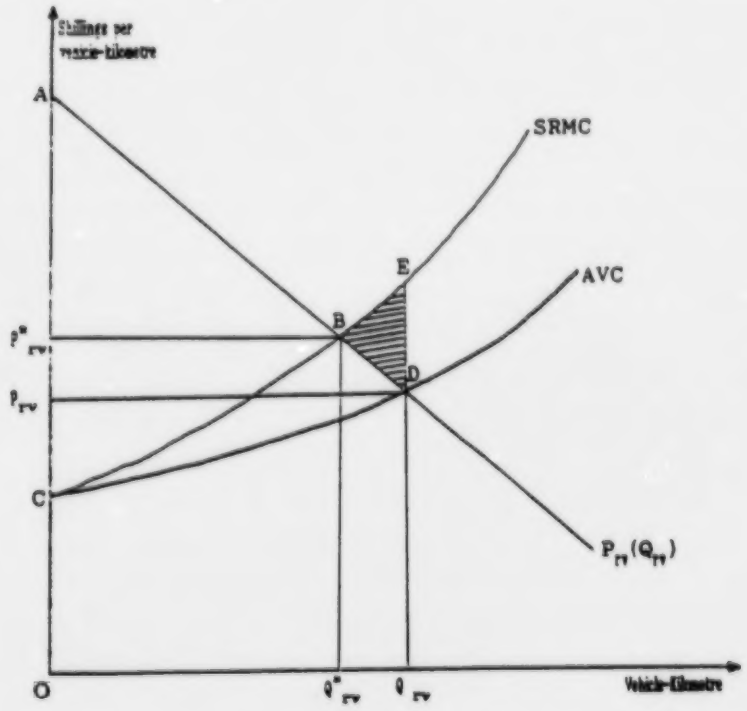


Figure 1: Public and Private Sector Benefits

is the private sector benefit (consumer surplus) under marginal cost pricing regime. The area $BCP^{*}_{rv}$ measures public sector benefit. Total Net Benefit is given by the area under the demand curve and above the short run marginal cost curve, that is, CAB. If average variable cost pricing is used, the society faces a welfare loss of BED. The method of pricing used in this study, however, would lead to prices that are lower than prices generated by marginal cost pricing but larger than prices generated by average cost pricing. It therefore minimizes welfare loss and at the same time leads to redistribution of income. This partially explains why pricing policy adopted in this study is preferred to the average cost pricing.

In order to take into account income distribution we must weight each sector gains. If weighting is done by the public sector gains so that the net benefit to the public sector has a unitary weight, then we obtain the same expression as the one on page 12.

Following the approach of Squire and Van der Tak, we further assume that consumer surplus that accrues to the private sector is a direct valuation of well being rather than an increase in income part of which may be saved or consumed. This implies that the model is a pure measure of benefits to the public and private sectors. The net social benefit function can be expressed as

$$NB = \sum_{r} \sum_{v} [F_{rv}(Q_{rv}) - C_{rv}(Q_{rv}) - m_{rv}(Q_{rv})] + [m_{rv}(Q_{rv})]\, w_{rv} \qquad (2.6)$$

where $w_{rv}$ is the weight attached to the private sector gain relative to the public sector. Differentiating (2.6) with respect to $Q_{rv}$ we get

$$\frac{\partial NB}{\partial Q_{rv}} = [F'_{rv}(Q_{rv}) - C'_{rv}(Q_{rv}) - m'_{rv}(Q_{rv})] + w_{rv}\, m'_{rv}(Q_{rv}) = 0 \qquad (2.7)$$

Rearranging[4] we obtain

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[4] See complete derivations and definitions in Appendix I.

$$[F'_{rv}(Q_{rv}) - C'_{rv}(Q_{rv})] - [F'_{rv}(Q_{rv}) - MR_{rv}] + w_{rv}\,[F'_{rv}(Q_{rv}) - MR_{rv}] = 0 \qquad (2.8)$$

Equation (2.8) can be expressed in terms of $P_{rv}$ to become

$$w_{rv}\,P_{rv} = MC_{rv} - (1 - w_{rv})\,MR_{rv}$$

The derived optimal price formula containing both efficiency and distributive aspects is

$$P_{rv} = \frac{1}{w_{rv}}\,MC_{rv} - \frac{(1 - w_{rv})}{w_{rv}}\,MR_{rv} \qquad (2.9)$$

This expression insures a price which maximises net benefits. For some critical value of $w_{rv} = 1$ the model seizes to account for distributional considerations but generates marginal cost prices. And when $w_{rv}$ is different from one, we obtain prices with some degree of efficiency as well as distributional considerations. While the framework of analysis presented above is an extension of the work done by Kirkpatrick [1979] it differs in several aspects.

The first point of departure is the definition of costs of road use. We assume that variable costs of road use are invariant to road size. Instead they are based on the short run marginal costs which includes vehicle operation costs, road costs and accident costs. This definition is an improvement over the one adopted by the Kenya-Danida study which yielded SRMC that are below AVC. In his estimates Kirkpatrick presents the average variable costs for different vehicle classes for paved roads only. A comparison of Kirkpatrick's AVC with Kenya-Danida SRMC are presented in Table 3 (next page). In contrast short run marginal cost adopted for this analysis are disaggregated both by vehicle class and road type, and are presented in Table 4 (on page 16).

Table 3: Comparison of AVC and SRMC - Shs. per vehicle-kilometre

| AVC | Paved | Unpaved |
|---|---|---|
| Passengers Cars | 0.012 | - |
| Light Goods Vehicles | 0.019 | - |
| Medium Goods Vehicles | 0.099 | - |
| Heavy Goods Vehicles | 0.186 | - |
| Buses | 0.124 | - |
| SRMC | | |
| Cars | 0.114 | 0.275 |
| Buses | 0.306 | 0.311 |
| Heavy Goods Vehicles | | |
| 2 Axle | 0.250 | 0.281 |
| 3 Axle | 0.341 | 0.383 |
| 4 Axle | 0.662 | 0.485 |
| 5 Axle | 0.824 | 0.587 |
| 6 Axle | 0.727 | 0.689 |

Note: The AVC have been converted from cents per vehicle-mile to shillings per vehicle-kilometre using the formula (1/100) Mile = 1.6093 Kilometre.

Sources: Kirkpatrick [1979, pp. 153], Kenya-Danida Study [1980, pp. 6-12]

Table 4: The Short Run Marginal Cost ($MC_{rv}$) Shs per vehicle-kilometre

| | Paved | Unpaved |
|---|---|---|
| Cars | 0.608 | 0.762 |
| Buses | 0.701 | 0.928 |
| Heavy Goods Vehicles | 1.565 | 1.566 |

Source: Kenya-Danida Study [1980, Tables 6-7 and 6-12].

Second, we have used the most recent information on the road network and vehicle kilometre for the period 1979 and 1988 to estimate the demand function. A brief examination of demand elasticities for the three vehicle categories is also made. This is a new contribution to the previous study by Kirkpatrick. The model therefore allows the maximisation of the net benefit function in parts. This is further enhanced by the disaggregation of demand by road type and vehicle classes discussed earlier. The significance of vehicle disaggregation is that they correspond to different social classes in the economy.

## 3.0 ESTIMATION OF THE DEMAND AND PARAMETERS OF THE MODEL

In this section the demand function is estimated. Definitions and estimates of the parameters of equation (2.9) in section 2 are also presented. We begin with estimating the demand function and marginal revenue estimates ($MR_{rv}$) in section 3.1. In sections 3.2, 3.3 and 3.4 definitions and values of $w_{rv}$, d and MPK are given.

### 3. The Demand Function

To estimate the demand function we have used the data from Traffic Statistics: 60-Point census to obtain the values of $Q_{rv}$ [MOPW, Traffic Statistics, 1979-1988]. One problem with vehicle-kilometre as a measure of road use is that, it varies from year to year and from place to place responding to different trip characteristics. Thus the measurement taken on a particular road reflect local conditions on that road rather than national trends. Such heterogeneity on the road system may mean that estimates from sampled roads introduce sample errors that weaken the possibility of generalization. This has been taken into account by regrouping the data to suit our purpose hence enabling us to generalize our results. Furthermore, the design of the 60-Point census recognizes this and provides the most representative vehicle-kilometre on the total road system[5].

The available data on vehicle kilometre is for seven years, that is 1982 to 1988. Information on annual fuel [petrol and diesel] consumption is available for most years. Since a sample size of seven years is relatively small we increased it to ten by estimating for the missing periods. This

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[5] The principal design is that traffic counts are carried out at a number of points chosen such as to make traffic flows observed there most representative of those on total road system. If census points are randomly chosen on a set of roads so that each point has the same chance of inclusion, then traffic flows in a day or month at the census point will be random sample flows on roads as a whole, ..., The number of points (N) is arbitrary and the more they are the greater the accuracy of estimation [Traffic Statistics 60-Point Traffic Census 1988, pp. 3]

enabled us to improve the estimates of transport demand.

The procedure of estimating $Q_{rv}$ for the missing periods is as follows. We first regressed $Q_{rv}$ on total petrol and diesel fuel consumption ($TFC_i$). Secondly, we used the resulting parameter estimates to forecast the amount of travel for the missing periods. Assuming that efficiency and composition of vehicles within each classification is unchanged, this regression should yield a measure of fuel consumption per vehicle-kilometre. It is also expected that vehicle-kilometre should increase with increases in fuel consumption. To compare the resulting parameter estimates we used quadratic and linear functional forms. The two equations[6] are

$$Q_{rv} = \hat{\alpha}_0 + \hat{\alpha}_1 TFC_i + \hat{\alpha}_2 TFC_i^2 \qquad (3.10)$$

$$Q_{rv} = \hat{\beta}_0 + \hat{\beta}_1 TFC_i \qquad (3.11)$$

Table 5 (next page), reports the results of these regression equations. The Table shows that a relatively large proportion of vehicle-kilometre (above 75 per cent) is explained by the regression equation, thus supporting our assumptions. This high degree of explanation is not surprising, however, given the limited number of observations used for the estimation. The quadratic equation yield significant parameter estimates for $Cars^{paved+unpaved}$ and $Buses^{unpaved}$. For the remaining categories of demand the parameter estimates are not, however, significant. In the linear estimate the value of $R^2$ remains relatively high (above 80 per cent) except for $Buses^{unpaved}$ and $HGoods^{paved+unpaved}$ which have relatively low $R^2$ (below 60 per cent). The t-statistics are nonetheless highly significant in all the demands. Despite low t-statistic in some categories of demand in the quadratic equation, the resulting values of $R^2$ are certainly superior to those obtained in the linear equation. We have therefore used the parameter estimates from quadratic regression equation for forecasting.

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[6] The intercepts included in these equations do not have any significant economic meaning other than to improve econometric fit of the data.

Table 5: Regression Results of Estimated Parameters[7]

| Quadratic Form: | C | TFC | $TFC^2$ | $R^2$ |
|---|---|---|---|---|
| $Cars^{paved}$ | 0.625E+08<br>(1.67) | -0.44E+06<br>(-1.7) | 830.45<br>(1.87) | 0.92 |
| $Cars^{unpaved}$ | 0.173E+08<br>(2.62) | -0.13E+06<br>(-2.79) | 246.11<br>(3.12) | 0.97 |
| $Buses^{paved}$ | 0.49E+06<br>(0.11) | 263.38<br>(0.13) | 4.96<br>(0.23) | 0.81 |
| $Buses^{unpaved}$ | 0.26E+07<br>(2.05) | -10826<br>(-1.97) | 12.399<br>(2.14) | 0.75 |
| $HGoods^{paved}$ | -0.55E+06<br>(-0.41) | 3423.2<br>(0.59) | -2.856<br>(-0.47) | 0.75 |
| $HGoods^{unpaved}$ | 93494<br>(0.87) | -442.24<br>(-0.95) | 0.547<br>(1.12) | 0.69 |
| Linear Form: | | | | |
| $Cars^{paved}$ | -0.73E+07<br>(-0.31) | 42857<br>(5.19) | | 0.84 |
| $Cars^{unpaved}$ | -0.34E+07<br>(-5.91) | 15249<br>(7.68) | | 0.92 |
| $Buses^{paved}$ | -0.59E+06<br>(-1.21) | 4947.9<br>(4.71) | | 0.82 |
| $Buses^{unpaved}$ | -94070<br>(-0.48) | 882.95<br>(2.1) | | 0.47 |
| $HGoods^{paved}$ | 73202<br>(0.511) | 725<br>(2.36) | | 0.52 |
| $HGoods^{unpaved}$ | -25742<br>(-1.99) | 74.19<br>(2.67) | | 0.59 |

[7] Even though the values of the coefficients of TFC and $TFC^2$ (i.e. in the quadratic equation) are negative in some cases, the sum of the partial derivative of $Q_{rv}$ with respect to TFC and $TFC^2$ have been verified to be positive for the entire sample. Figures in parenthesis are the corresponding t-values.

The forecast demand for 1979, 1980 and 1981 and the observed demand for 1982 to 1988 were then regressed on the real values of fuel prices and GDP. The general form of the estimated equation is

$$Q_{rv} = \beta_0 + \beta_1 P_v + \beta_2 GDP \qquad (3.12)$$

Various functional forms for the variable were tried. Of these the log-linear and linear functional forms yielded similar results. The results of these estimates are reported in Table 6 (next page). Although the results are comparable, linear equation yield better results. Whereas the values of $R^2$ are not high in most of the estimated demands except in the case of $Buses^{paved}$ and $HGoods^{paved+unpaved}$, the coefficients have the appropriate signs as we expected. In most cases parameter estimates of income are significant, as opposed to those of price which are generally not significant.

The obtained price and income elasticities of demand are different between themselves and are different from unity, thus strengthening our reasoning for disaggregation. Like the parameter estimates the elasticities have appropriate signs and are according to our expectation (see the next paragraph). The only surprising result is the high income elasticity of demand (about 5) for $HGoods^{unpaved}$. A possible explanation is that, during 1977/1978 Kenya experienced a boom in the export of coffee. This led to fast increase in the GDP which could have possibly led to a more than proportional increase in the vehicle-kilometre accounted for partly by the local traffic and transit traffic. The transit traffic is largely from Uganda which relies on Kenyan roads for transporting its import and export commodities. This may have led to vehicle-kilometre that are highly sensitive to changes in GDP among the heavy goods vehicle category.

A priori we expect that vehicle operation costs are higher on unpaved roads than they are on the paved roads. For this reason price elasticities should be higher on unpaved roads than they are on paved roads. As is clear from Table 6, price elasticities of vehicle-kilometre by cars, buses and Heavy goods vehicles are higher on unpaved roads than on the paved roads. Income elasticities on

Table 6: Elasticity Results of the Estimated Equations

| | $n_p$ | $n_{gdp}$ | $R^2$ |
|---|---|---|---|
| Linear Form: | | | |
| $Cars^{paved}$ | -0.390<br>(-0.88) | 1.144<br>(2.2) | 0.44 |
| $Cars^{unpaved}$ | -0.574<br>(-0.73) | 1.782<br>(1.92) | 0.37 |
| $Buses^{paved}$ | -0.262<br>(-1.16) | 1.864<br>(6.63) | 0.86 |
| $Buses^{unpaved}$ | -0.435<br>(-0.83) | 1.237<br>(1.88) | 0.36 |
| $HGoods^{paved}$ | -0.003<br>(-0.01) | 1.288<br>(4.17) | 0.72 |
| $HGoods^{unpaved}$ | -1.487<br>(-1.18) | 5.365<br>(3.4) | 0.63 |
| Log-Linear Form: | | | |
| $Cars^{paved}$ | -0.381<br>(-1.07) | 1.206<br>(2.00) | 0.47 |
| $Cars^{unpaved}$ | -0.549<br>(-0.95) | 1.982<br>(1.66) | 0.43 |
| $Buses^{paved}$ | -0.300<br>(-1.44) | 1.870<br>(6.21) | 0.86 |
| $Buses^{unpaved}$ | -0.611<br>(-1.12) | 1.060<br>(1.23) | 0.29 |
| $HGoods^{paved}$ | -0.008<br>(-0.03) | 1.284<br>(3.97) | 0.72 |
| $HGoods^{unpaved}$ | -1.812<br>(-1.43) | 5.123<br>(1.71) | 0.60 |

Notes: 1. $n_p$ = price elasticity

2. $n_{gdp}$ = income elasticity

3. ( ) are the respective t - values

the other hand are higher on the unpaved roads for cars and Heavy goods vehicles. For buses income elasticity is higher on the paved roads, but low on the unpaved roads. The latter may suggest that as income rises there is tendency among the bus users to change their mode of travel. Based on these results we deduce that price and income elasticities of vehicle-kilometre are higher on the unpaved than on the paved roads except for buses. We thus conclude that, price and income elasticities of $Q_{rv}$ are higher on unpaved than on paved roads. These results indicate that changes in fuel prices and income are important determinants of the amount of travel made by each vehicle category. Income seems to be a strong determinant of vehicle-kilometre by buses on paved roads.

From equation (2.9) of section 2, it is clear that, the values of $P_{rv}$ are determined by marginal cost ($MC_{rv}$), marginal revenue ($MR_{rv}$) and the weight attached to the private sector relative to that of the public sector ($w_{rv}$). Marginal revenue values (see Table 7), have been computed from both equation (2.8) in Appendix I and the regression equation (3.12). It should be noted that, price in the regression equation [$P_v$] is defined as shillings per litre of petrol or diesel, whichever applies to a given vehicle category. To maintain uniformity in the units of measurement, we have to convert the coefficient of $P_v$ which measures shillings per litre of fuel to a measure of litres of fuel per vehicle kilometre. This entails measuring the efficiency of fuel consumption on different roads by different class of vehicles[8].

[8] The computed efficiency ratios are [(0.007, 0.022); (0.00004, 0.00867) and (0.0046, 0.016)] for cars, buses and heavy goods vehicle. The first set of figures in each parenthesis represent efficiency on paved roads while the second set of figures stand for efficiency on the unpaved roads. In each case we observe that fuel consumption per vehicle kilometre is lower on paved than on unpaved roads.

Table 7: Marginal Revenue Values ($MR_{rv}$) Shs. per vehicle-kilometre

| | Paved | Unpaved |
|---|---|---|
| Cars | 0.613 | 0.655 |
| Buses | 0.496 | 0.89 |
| Heavy Goods Vehicles | 1.56 | 1.562 |

### 3.2 The Value of $w_{rv}$

Following Van der Tak [1975], $w_{rv}$ is defined as the value of marginal increase in consumption to a particular group relative to public sector income. It can be thought of as being composed of two parts. First, is the value of marginal increase in consumption to someone at a level of consumption ($W_c$) divided by the value of marginal increase in consumption accruing to someone at the average level of consumption ($W_{\bar{c}}$). This is denoted by $d = W_c/W_{\bar{c}}$. Second, is the value of marginal increase in consumption to someone at the average level of consumption ($W_c$) divided by the value of marginal increase in public income ($W_g$) and is denoted by $MPK = W_{\bar{c}}/W_g$.

The value of $w_{rv}$ can therefore be expressed in terms of d and MPK as shown below

$$w_{rv} = \frac{W_c}{W_{\bar{c}}} \cdot \frac{W_{\bar{c}}}{W_g} = d.\left(\frac{1}{MPK}\right) \qquad (3.13)$$

If benefits accrue to the average person, so that the gains to all individuals are valued equally (i.e. $W_{\bar{c}} = W_c$) then $d = 1$. If greater weight is attached to consumption gains to the impoverished than to the affluent members in the economy ($W_c > W_{\bar{c}}$), then $d > 1$. On the contrary

if $W_c < W_{\bar{c}}$, we have $d < 1$ implying greater weight is given to the affluent. The latter case should not be a reasonable assumption in the presence of income disparities. Instead it is plausible to assume that the government attaches greater weight to the less fortunate. It is in this line of argument that we proceed to estimate $w_{rv}$ based on the already defined values of d and MPK.

### 3.3 The value of d

To derive the distribution weights, we first assume that there exist some "social welfare function". The social welfare function is supposed to be some sort of utility function denoted by

$$U = U(U_1, U_i, \ldots, U_n) \qquad (3.14)$$

resulting from any distribution $(U_1, U_i, \ldots, U_n)$ of private utilities. The aggregate social welfare utility function can therefore be expressed as

$$W(U(X)) = \Sigma a_c U_c(X_c) \qquad (3.15)$$

where the parameter $a_c$ is related to the welfare weights of individual economic agents and X is a vector of consumption goods[9]. These weights represent the value judgements of the social planner.

Whereas the social utility function just described corresponds to the general form of social utility function we will confine ourselves to the constant elasticity[10] type of utility function.

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[9] See for example, Varian H. R. [1984, pp. 275]

[10] This type of utility function has been extensively discussed by Squire and Van der Tak [1975, pp. 63 - 67], Scott et al [1976, pp. 49 - 54], Taylor L. [1979, Chapter 8].

We denote this by

$$U_c = C^{-\theta} = \frac{1}{C^{\theta}} \qquad (3.16)$$

where C is consumption and $\theta$ is the consumption elasticity of utility. An important property of this type of utility function is that it assumes diminishing marginal utility of consumption. The parameter $\theta$ can easily be interpreted. A higher value of $\theta$ implies a high rate of diminishing marginal utility, hence the more egalitarian is the policy objective. Put more explicitly, a value of $\theta = 1$ implies quite pronounced policy bias in favour of less privileged members in the economy, hence the weight of marginal consumption decreases proportionately with increases in the existing level of consumption[11]. Likewise $\theta = 2$ lead to a set of weights that imply a marked egalitarian bias [Squire and Van der Tak 1975, pp. 64]. As is shown later in the paper, it is more reasonable for a country that is characterised with high income disparities as Kenya is, to adopt more egalitarian policies, hence select a high value of $\theta$.

To compare the value of consumption to different income groups, we need some yardstick such as average consumption. Inasmuch as consumption and income are different ways of expressing the same thing we can use the two interchangeably without loss of meaning. A measure of distribution weights d, takes the form

$$d = \frac{U_c}{U_{\bar{c}}} = \left(\frac{\bar{C}}{C}\right)^{\theta} \qquad (3.17)$$

From this expression we can derive the weights to be given to marginal increases in income

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[11] It is well known that consumption measures the volume of goods and services actually consumed, so it could be equated with material welfare. But income represents *potential consumption*, including a part of the potential which is not realized in the current period because it is saved for higher consumption later. In this sense consumption and income serves the same goal. Diminishing marginal utility of consumption is considered analogous to diminishing marginal utility of income.

(consumption) at any income level. What we need at this stage is information on income distribution for rural and urban households. While it is true in Kenya, that many poor people live in the urban centres, most of the poorest people tend to live in the rural areas where approximately 85 per cent of the population lives. The wealthy on the other hand tend to live in the urban areas.

There are two possible sources of rural income distribution in Kenya. The first, is the Central Province Survey of 1968-1969 based on the ILO Report, 1972 and reported in Scott [February, 1973] and Scott et al [1976]. Ostensibly, this survey covered 20 to 25 per cent of the rural African population. The second one, is the 1981/1982 "Rural Household Budget Survey" which gives information on rural household income for the country and covered a sample of 2.8 per cent of the total rural population. The problem with these two surveys is the dissimilarities of income groups used in each and their incompatibility with income groups used in the urban distribution data. Inevitably, it is difficult to compare the results of these surveys with urban distribution data without introducing complexities. Consequently, in the absence of appropriate information on the pattern of rural income which is directly comparable to and compatible with urban distribution data, we have assumed that the distribution of income in rural and urban sectors are similar and simply adjust for price[12] differentials between the two sectors.

For the urban sector the main source of household income is the official survey of urban households in Nairobi, Mombasa and Kisumu which was conducted in 1968-1969[13]. Scott et al [1976] used the data for Mathare Valley Survey to adjust the urban household survey for under-representation of the poor living in the urban slum areas. The weighted average income levels are KShs.4735 and KShs.8050 per annum for rural and urban households respectively. Table 8 presents

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[12] Based on the rural target incomes given by the ILO Report [1972] and reported in Kirkpatrick pp.146, the ratio of urban to rural prices was taken to be 1.7:1.

[13] Details of the survey are contained in the ILO Report [1972, Technical Paper No. 4]

the adjusted estimates of urban household income distribution (shown in columns 1, 2 and 3) and the weights attached to each income group.

Table 8: Distribution of urban household incomes and weights attached to each income group (Income in KShs per annum)

| (1) Income Group | (2) Income per HH | (3) % of HH | (4) (2)/Average[1] | (5) Weights[2] |
|---|---|---|---|---|
| Up to 3000 | 1425 | 22.0 | 0.18 | 5.5 |
| 3000 - 4500 | 3025 | 15.0 | 0.37 | 2.7 |
| 4500 - 6000 | 4150 | 11.5 | 0.51 | 2.0 |
| 4800 - 7500 | 5450 | 8.9 | 0.68 | 1.5 |
| 7500 - 10500 | 7175 | 13.1 | 0.89 | 1.1 |
| 10500 - 12000 | 10275 | 10.6 | 1.30 | 0.8 |
| 12000 - 21000 | 14325 | 7.1 | 1.80 | 0.5 |
| 21000 - 30000 | 20050 | 6.4 | 2.50 | 0.4 |
| above 30000 | 36550 | 5.4 | 4.50 | 0.2 |

Notes: 1: Average income for urban household is KShs.8050.

2: Reciprocal of column four.

Source: Scott et al [1976, Table 4.4]

Even though the parameter $\Theta$ has a straightforward intuitive meaning, its value is not easy to determine. While government policy documents reflect the desire to attach more weight to the poor, the rate at which the weight falls as income rises is not significant [Scott et al 1976, pp. 56-57]. In their estimates Scott et al used a $\Theta$ value of one. We use the same value of $\Theta$, however, for

comparison purposes we also use other values of $\Theta$ such as 0, 0.5, 1.5 and 2.

Information on the pattern of income distribution presented in Table 8, average level of income (C) and the values of $\Theta$ have been used to calculate the interpersonal distribution weights, given in Table 9. The Table shows that interpersonal distribution weights are sensitive to the marginal utility of elasticities used. Marginal utility of consumption gains is higher among the poor than among the rich[14].

The decision to or not to increase the consumption in the private sector *vis-a-vis* increasing public consumption is dependent on what the government considers to be "the critical level of income (consumption)". At the critical level of consumption the government values marginal increase in private consumption equally with marginal increase in its income. Scott et al [1976] examined the threshold level of income for personal tax liability and for welfare receipts, and concluded that the recommended minimum household target income levels by the ILO Report [1972], provide reasonable estimate of the government's implicit critical consumption level[15]. These target incomes were estimated for 1979 and 1985. Kirkpatrick used the 1979 income targets in his study, we however adopt the 1985 income targets which yields KShs.2160 and 3000 for rural and urban households respectively.

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[14] The terminologies "the poor" and "the rich" are used in relative terms. Those with incomes below the average are termed the poor. And those whose income lies above the average level are considered as the rich.

[15] The ILO Report [1972, pp. 109-110]

Table 9[16]: Values of consumption distribution weights (d) for marginal changes in consumption

| Consumption level at: | | And when θ equals | | | | |
|---|---|---|---|---|---|---|
| (C) | ($\bar{C}$/C) | 0 | 0.5 | 1.0 | 1.5 | 2.0 |
| 1425 | 5.6 | 1 | 2.34 | 5.5 | 12.9 | 30.25 |
| 3025 | 2.7 | 1 | 1.64 | 2.7 | 4.43 | 7.29 |
| 4150 | 2.0 | 1 | 1.41 | 2.0 | 2.83 | 4.00 |
| 5450 | 1.5 | 1 | 1.22 | 1.5 | 1.84 | 2.25 |
| 7175 | 1.1 | 1 | 1.05 | 1.1 | 1.15 | 1.21 |
| 10275 | 0.8 | 1 | 0.89 | 0.8 | 0.72 | 0.64 |
| 14325 | 0.5 | 1 | 0.71 | 0.5 | 0.35 | 0.25 |
| 20050 | 0.4 | 1 | 0.63 | 0.4 | 0.25 | 0.16 |
| 36550 | 0.2 | 1 | 0.45 | 0.2 | 0.09 | 0.04 |

Source : Derived from Table 8.

### 3.4 The Value of MPK

As previously defined the parameter MPK is the value of marginal increase in public income weighted by the marginal increase of income of someone at the average level of consumption. It may also be interpreted as the relative valuation of future versus present consumption. The economic significance

[16] Squire and Van der Tak [1975, pp. 64] points out, that only one such table is required for all countries, because the only information required is the ratio of the existing consumption level, which is a pure number (see column 2 of Table 6). Though relevant, the value of d may vary over time as income grows for particular income groups.

of **MPK** can be viewed from the standpoint of the government's relative valuation of investment and consumption. That future consumption depends on the foregone present consumption (returns to investment) suggests that marginal productivity of capital or the present value of future consumption plays an important role in determining the value of **MPK**.

The parameter **MPK** can be measured in several ways. Sen [1964] and later Little and Mirlees [1975] suggested an approach in which the time horizon acceptable to society is taken into account in calculating the present value of the future consumption gains resulting from present investment relative to foregone current consumption. Kirkpatrick [1976] followed the approach of Van der Tak [1975] which estimates the value of **MPK** by summing up the discounted values of marginal productivity of capital. The two methods are not significantly different mainly because current investments determine the level of future income hence, future consumption. Marginal productivity of capital is dependent on investment and indirectly influences future income. We use the latter approach for our analysis.

It is worth noting that, the value of **MPK** would depend on the marginal productivity of capital (q) and a consumption discount rate chosen (i). This can be expressed as

$$MPK = \sum_{t=0}^{\infty} \frac{q_t}{(1+i)^t} = \left(\frac{q_t}{i}\right) \qquad (3.18)$$

Given the values of q and i, different levels of **MPK** can be calculated. Equation (3.18) enables us to estimate the value of ($\bar{C}$/C) at which the government is indifferent between its income and private consumption, so that costs and benefits of increased consumption are equalized. This is the critical level of consumption at which $w_{rv}$ equals to one.

An alternative measure, is to allow for the reinvestment of income that accrues to the government. Retaining the assumptions of i) equal valuation of consumption at the average are and

ii) that private savings are as good as public investment, MPK can be expressed as

$$MPK = \left[\frac{q - sq}{i - sq}\right] \qquad (3.19)$$

where (1 - s) is equivalent to the proportion of returns consumed at the average level of consumption. In this case information needed to estimate the value of MPK are marginal productivity of capital, consumption discount rate and savings rate. The value for the marginal productivity of capital is assumed to be 15 per cent, based on the estimates of Scott et al [1976, pp.135]. The difficulty of getting reliable information on income and expenditure is already mentioned. What this suggests is that, cross-section average savings or marginal propensity to save obtainable from such income and expenditure information are bound to be unreliable. The marginal propensity to save is therefore assumed to be 10 per cent. This is based on Scott who fitted a linear saving function to the urban household survey data.

The consumption discount rate depends on a number of considerations. First, if the average level of consumption grows through time, then the discount rate will reflect both diminishing marginal utility and growth in consumption. In addition it will also reflect pure rate of time preference (δ). The expression for the consumption discount rate[17] is

$$i = \theta g + \delta \qquad (3.20)$$

The value of pure rate of time preference δ is based on subjective judgement and is generally assumed to lie between 0 and 5 per cent. A good indicator of the value of δ is its relationship with θ and i. For example a government that is committed to raising GDP growth as well as distributional issues would have a relatively high value of θ and a relatively low consumption discount rate, hence low value of δ.

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[17] Full derivation of i is presented in Appendix II.

Suppose the values of $\delta = 0.025$, $g = 0.01$ and $\Theta = 1$, the value of $i = 0.035$. Different values of i presented in Table 10 can be calculated using alternative values of $\Theta$ and $\delta$. It should be noted

Table 10: Values of consumption discount rate (i)

| | $\Theta$=0.5 | $\Theta$=1.0 | $\Theta$=1.5 | $\Theta$=2.0 |
|---|---|---|---|---|
| $\delta$=0.015 | 0.020 | 0.025 | 0.030 | 0.035 |
| $\delta$=0.025 | 0.030 | 0.035 | 0.040 | 0.045 |
| $\delta$=0.030 | 0.035 | 0.040 | 0.045 | 0.050 |
| $\delta$=0.040 | 0.045 | 0.050 | 0.055 | 0.060 |
| $\delta$=0.050 | 0.055 | 0.060 | 0.065 | 0.070 |

however that, if g is different from 1 per cent, the resulting values of i in Table 10 will not remain the same. For instance a g of 3 per cent would yield i value of 0.055.

From the i values in Table 10 and making use of equation (3.18) we can compute values of MPK as reported in Table 11. The estimated values of MPK must be interpreted with caution. An important cross-check is to find out whether the estimated value of MPK satisfies the critical level of consumption (i.e. $w_{rv} = 1$). To illustrate this point, suppose, that we that we pick MPK value of 2.7 from Table 11, a value of $w_{rv} = 1$ would require an identical value of d.

Reading off from Table 8 page 27, a value of $d = 2.7$ would apply to the bottom 37 per cent of households. It is also clear from the same Table that this value corresponds to household

Table 11: Estimates of the values of MPK

| Values of i | Values of MPK |
|---|---|
| 0.025 | 13.5 |
| 0.03 | 9.0 |
| 0.035 | 6.75 |
| 0.040 | 5.4 |
| 0.050 | 3.85 |
| 0.060 | 3.0 |
| 0.065 | 2.7 |

incomes[18] of less than KShs.4500 per annum (urban) and KShs.2647 per annum (rural). These income levels compares reasonably well with the targets set by the ILO Report [1972] which were KShs.3000 per annum (urban households) and KShs.2160 per annum (rural households) for 1985. We therefore conclude that the alternative parameter estimates adopted in this study are consistent with those already established. In the subsequent calculations we assume that MPK = 3. The rationale being that, the implied consumption discount rate is closer to the value normally assumed for the social discount rate.

[18] Incomes in 1972 prices.

## 4.0 ESTIMATES OF OPTIMAL ROAD USER CHARGES

In this section we first present a brief discussion of distribution weights by vehicle types. We then proceed to estimate the optimum level of road user charges. Finally our estimates are compared with charges based on efficiency considerations alone and the existing level of road user charges.

In section 3.3 we calculated different values of d based on the information about income distribution and different values of $\Theta$. In order that we calculate the optimal road user charges appropriate values of d need to be used. This requires that we consider the income groups within which road users fall. Information on income characteristics of vehicle occupants is hard to come by. However, Howe [1971] estimated incomes within which road users can be categorised. His estimates show that the annual income of those who travel by cars and buses is about KShs.18800 and KShs.5650 respectively. For consistency with figures presented in Table 6 these income levels are adjusted by a factor of 1.25 to become KShs.23500 and KShs.7062.5. The adjustment simply transforms the implicit critical consumption level for 1979 to that of 1985. Furthermore Kirkpatrick [1979, pp. 153] notes that there is an implicit upward bias in the Howe estimates introduced by the assumption of regular and continuous employment throughout the year and by limiting the survey only to those who travelled on business. He corrected this bias and the revised the figures for travel by buses are KShs.4500 in the urban and KShs.3750 in the rural. Comparing these figures with those in Table 8 indicates that use of cars is concentrated among the high income groups. Based on these figures Kirkpatrick calculated d values of 0.26 and 1.75 for cars and buses respectively. The Heavy goods vehicles category is assumed to operate under competitive conditions and that benefit of road transport accrues equally to consumers and producers of the transported merchandise. For this category, the d value was estimated as the average of all income group weights, weighted by their share in total income and this was found to be 2.3. The estimated distribution weights attached to each class of vehicles are summarised in Table 12 (next page).

Table 12: Distribution Weights by Vehicle Type

| | Distribution Weights | | | | |
|---|---|---|---|---|---|
| | $\theta$=0 | $\theta$=0.5 | $\theta$=1 | $\theta$=1.5 | $\theta$=2 |
| Cars | 1 | 0.51 | 0.26 | 0.13 | 0.067 |
| Buses | 1 | 1.32 | 1.75 | 2.31 | 3.062 |
| HGoods | 1 | 1.51 | 2.3 | 3.48 | 5.29 |

Source: Computed from different incomes of vehicle occupants.

Finally we require estimates of the elasticity of demand for road use. The demand estimates discussed in section 3 show that price elasticities are relatively low on paved roads for cars, buses and heavy goods vehicles. The low elasticities can be explained by the fact that, since travel by cars is undertaken by the most affluent members of the society, longer travel times, congestion and inconvenience of bus travel, discourage them to switch travel modes. Limited geographical coverage and sluggish rail transport imply that bus travellers hardly have any alternative for long distance travels. And in the case of heavy goods demand elasticities is almost insignificant on the paved roads. This may be explained by the fact that, for many commodities transport cost represent only a small proportion of total costs.

Having estimated all the components of the model $MC_{rv}$, $MR_{rv}$ and $w_{rv}$, we proceed to calculate the optimal level of road user charges ($P_{rv}$) using equation (2.9) of section 2. The existing and efficient road user charges, and the resulting optimal user estimates are reported in Table 13 (next page). It is clear from the Table that optimal user charges are lower than the SRMC. These results are attributed to the elastic transport demand and the resulting marginal revenues which are positive.

Two points worth noting are that; [i] the estimated optimal road user charges are higher than the existing charges and are lower than efficient charges and [ii] the distributional weights lead to user charges which tend to favour the use of paved roads.

Table 13: Existing Road User Charges, Efficiency Charges and Estimates of Optimal Road User Charges (Shillings per vehicle-kilometre)

| | Existing Charges[1] | | Efficient Charges | | Optimal Charges[2] | |
|---|---|---|---|---|---|---|
| | Paved | Unpaved | Paved | Unpaved | Paved | Unpaved |
| Cars | 0.49 | 0.48 | 0.61 | 0.76 | 0.55 | 0.65 |
| | | | (24.5)[3] | (58.3) | (12.2) | (35.4) |
| Buses | 0.39 | 0.62 | 0.70 | 0.93 | 0.66 | 0.89 |
| | | | (77.2) | (50.0) | (67.1) | (43.5) |
| HGoods | 0.84 | 0.87 | 1.57 | 1.56 | 1.56 | 1.56 |
| | | | (86.7) | (77.9) | (86.2) | (86.4) |

Note: 1) Existing road user charges are obtained from the Kenya-Danida Study [1980, Table 6.03]

2) The optimal road user charges are based on $w_{rv}$ values of 0.086, 0.583 and 0.766 for cars, buses and heavy goods vehicles respectively.

3) Figures in ( ) are the percentage increases of the efficient charges and optimal prices over the existing charges.

From the estimated results it can be argued that road users have not been paying the true cost of their road use. This is reflected by the divergence of efficient and optimal charges from the existing road user charges. Consequently, the burden of paying for the social cost of road use falls

on society. One would also expect that, by applying explicit weighting to interpersonal distribution, the optimal road user charges should rise faster among car users than in other categories of vehicle users. To the contrary our results show that optimal user charges for cars is half that of efficient charges. This result is surprising but interesting. It is surprising because it contradicts the simplistic view that all car users fall in the higher income category in the society. It is interesting as it suggests that further disaggregation may be necessary. Optimal user charges for buses and heavy goods vehicles are however more realistic both from the practical and theoretical standpoints. For buses the optimal prices are below the efficient charges by about 10 per cent and 7 per cent for paved and unpaved roads respectively. As for heavy goods vehicles there is no significant difference between efficient and optimal charges. This result strengthens our assumption of perfect competition in the distribution industry. Despite the surprising optimal user charge for cars, resulting user charges based on distributional considerations show some redistribution reflected in the charges for each vehicle category.

## 5.0 CONCLUSION

The aim of this study has been to derive a method of calculating the optimum level of road user charges taking into account the distributional effects. It has also been concerned with the application a single pricing policy as opposed to average cost pricing. We have used the Traffic census data to illustrate empirically the application of these theoretical concepts.

The results obtained are based on a variety[19] of assumptions. Accuracy of our results depend upon sufficient and reliability of data. Notwithstanding these qualifications, the analysis confirms that price and income are important determinants of the amount of travel. Price elasticities are low but reasonable as was expected and also empirically verified in the main text. By applying a second best pricing method the study confirms that there is a large social cost to society resulting from vehicle operation. This can be seen in the differences between the efficient and optimal charges obtained and the existing road user charges. Inclusion of distributional considerations yield diverging results from those obtained from pure efficiency objectives.

Two policy issues emerge from these results. First, the Kenyan government should include distributional considerations when designing road user charges. Secondly, the proposed second best pricing policy should be used in place of the average cost pricing because it minimizes welfare loss and achieves income redistribution. Implementation of these policies should not be difficult nor expensive since the model is designed to handle both at the same time.

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[19] Appendix III gives the results on the sensitivity analysis.

## APPENDIX I: DERIVATION AND DEFINITIONS OF THE MODEL

$$P_{rv} = P_{rv}(Q_{rv}) \qquad (2.1)$$

Is the inverse demand for road use. Subscripts represent road and vehicle type respectively.

The area under the demand curve is divided into two. The first part is the revenue to the government. The second part is the consumer surplus. The expression for this is

$$F_{rv}(Q_{rv}) = P_{rv} \cdot Q_{rv} + m_{rv}(Q_{rv}) \qquad (2.3)$$

Net Benefit to public sector can be expressed as

$$[F_{rv}(Q_{rv}) - C_{rv}(Q_{rv})] - [m_{rv}(Q_{rv})]$$

The net benefit function with distribution is

$$NB = \sum_r \sum_v [F_{rv}(Q_{rv}) - C_{rv}(Q_{rv}) - m_{rv}(Q_{rv})] + [m_{rv}(Q_{rv})] w_{rv} \qquad (2.6)$$

where the $w_{rv} = W_c/W_g$, implying unitary weight for public sector.

Differentiating (2.6) with respect to $Q_{rv}$ yields

$$\frac{\partial NB}{\partial Q_{rv}} = [F'_{rv}(Q_{rv}) - C'_{rv}(Q_{rv}) - m'_{rv}(Q_{rv})] + [m'_{rv}(Q_{rv})] w_{rv} \qquad (2.7)$$

We know that the consumer surplus equals the area under the demand curve less total revenue at the level of road use. We thus have

$$m_{rv}(Q_{rv}) = F_{rv}(Q_{rv}) - P_{rv} \cdot Q_{rv} = P_{rv}(Q_{rv}) \cdot Q_{rv} \qquad (2.7a)$$

The last term on the RHS obtains from our definition of the demand function. The change in consumer surplus due to changes in the amount of road use can be obtained by differentiating

equation (2.7a) to get

$$m'_{rv}(Q_{rv}) = F'_{rv}(Q_{rv}) - MR_{rv} \qquad (2.7b)$$

With this result equation (2.7) can be restated as

$$[F'_{rv}(Q_{rv}) - C'_{rv}(Q_{rv})] - [F'_{rv}(Q_{rv}) - MR_{rv}] + w_{rv}[F'_{rv}(Q_{rv}) - MR_{rv}] = 0 \qquad (2.8)$$

From equation (2.2) in the text we obtain $F'_{rv}(Q_{rv}) = P_{rv}$. Equation (2.8) can therefore be expressed in terms of price as

$$w_{rv}P_{rv} = MC_{rv} - (1-w_{rv})MR_{rv} \qquad (2.8a)$$

Consequently the optimal price formula incorporating the distribution aspects is easily derived and is expressed as

$$P_{rv} = \frac{1}{w_{rv}} MC_{rv} - \frac{(1-w_{rv})}{w_{rv}} MR_{rv} \qquad (2.9)$$

This expression is exactly identical to equation (2.9) in the main text.

## APPENDIX II:DERIVATION OF THE CONSUMPTION RATE OF DISCOUNT

$$W_{\bar{c}} = \bar{C}_t^{-\theta} e^{-\delta t} \qquad (3.1)$$

Equation (3.1) represent the weight attached to consumption at the average level discounted at the natural rate of pure time preference.

Taking the time derivative of equation (3.1) yields

$$\frac{dW_{\bar{c}}}{dt} = \dot{W}_{\bar{c}} = -\theta \bar{C}_t^{-\theta-1} \cdot \dot{\bar{C}}_t \cdot e^{-\delta t} - \delta \bar{C}_t^{-\theta} e^{-\delta t} = 0$$

Rearranging this expression and letting growth rate in consumption g to be a ratio of average consumption over time to the average consumption, that is,

($g = \dot{\bar{C}}_t / \bar{C}_t$) we obtain

$$\dot{W}_{\bar{c}} = -(\theta g + \delta)(\bar{C}_t^{-\theta} e^{-\delta t}) \qquad (3.2)$$

$$\dot{W}_{\bar{c}} = -(\theta g + \delta) W_{\bar{c}} \qquad (3.2a)$$

The consumption discount rate is defined in terms of average level of consumption and is given by

$$i = -\frac{\dot{W}_{\bar{c}}}{W_{\bar{c}}} \qquad (3.3)$$

Substituting equation (3.2a) into equation (3.3) yields

$$i = \theta g + \delta \qquad (3.4)$$

which equation (3.20) in the text. And

i = Consumption Discount rate.

$\theta$ = Elasticity of marginal social utility function.

$\delta$ = Pure rate of time preference.

g = Increase in Consumption.

## APPENDIX III: SENSITIVITY ANALYSIS

The following Tables show the sensitivity of optimal road user charges to variations in the parameter values. Various parameter values used are discussed in the main text (see Tables 8, 9, 10, 12 and 13). As in the text savings ratio is assumed to be 10 per cent.

| | | | Cars | |
|---|---|---|---|---|
| Parameter Values | | $w_{rv}$ | Paved | Unpaved |
| If | $\theta$ = 0.5 | | | |
| | d = 0.51 | | | |
| | v = 13.5 | 0.037 | 0.47 | 0.50 |
| | v = 4.5 | 0.113 | 0.57 | 0.68 |
| If | $\theta$ = 1.0 | | | |
| | d = 0.26 | | | |
| | v = 9 | 0.029 | 0.44 | 0.43 |
| | v = 3 | 0.086 | 0.55 | 0.65 |
| If | $\theta$ = 1.5 | | | |
| | d = 0.13 | | | |
| | v = 5.4 | 0.024 | 0.41 | 0.35 |
| | v = 2.7 | 0.048 | 0.51 | 0.56 |
| If | $\theta$ = 2.0 | | | |
| | d = 0.067 | | | |
| | v = 3.85 | 0.017 | 0.32 | 0.18 |
| | v = 2.45 | 0.027 | 0.43 | 0.40 |

**Buses**

| Parameter Values | | $w_{rv}$ | Paved | Unpaved |
|---|---|---|---|---|
| If | $\theta$ = 0.5 | | | |
| | d = 1.32 | | | |
| | v = 9 | 0.146 | 0.40 | 0.61 |
| | v = 3.75 | 0.352 | 0.61 | 0.83 |
| If | $\theta$ = 1 | | | |
| | d = 1.75 | | | |
| | v = 5.4 | 0.32 | 0.59 | 0.81 |
| | v = 3 | 0.58 | 0.66 | 0.89 |
| If | $\theta$ = 1.5 | | | |
| | d = 2.31 | | | |
| | v = 4.5 | 0.51 | 0.65 | 0.87 |
| | v = 2.7 | 0.85 | 0.69 | 0.92 |
| If | $\theta$ = 2.0 | | | |
| | d = 3.062 | | | |
| | v = 6.75 | 0.45 | 0.64 | 0.86 |
| | v = 3.857 | 0.79 | 0.68 | 0.91 |

**Heavy Goods Vehicles**

| Parameter Values | | $w_{rv}$ | Paved | Unpaved |
|---|---|---|---|---|
| If | $\theta$ = 0.5 | | | |
| | d = 1.51 | | | |
| | v = 9 | 0.167 | 1.59 | 1.58 |
| | v = 3.375 | 0.447 | 1.57 | 1.57 |
| If | $\theta$ = 1 | | | |
| | d = 2.3 | | | |
| | v = 9 | 0.25 | 1.58 | 1.57 |
| | v = 3 | 0.76 | 1.56 | 1.562 |
| If | $\theta$ = 1.5 | | | |
| | d = 3.48 | | | |
| | v = 5.4 | 0.64 | 1.56 | 1.57 |
| | v = 4.5 | 0.77 | 1.56 | 1.56 |
| If | $\theta$ = 2.0 | | | |
| | d = 5.29 | | | |
| | v = 6.75 | 0.78 | 1.56 | 1.56 |

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